



December 19, 2011

Department of Toxic Substance Control
ATTN: Chemical Information Call-in
Office of Pollution Prevention and Green Technology
P.O. Box 806
Sacramento, CA 95812-0806

RE: Response to Formal Request for Chemical Information and Analytical Test Methods for Specified Nanomaterials

To Chemical Information Call-in:

Cambrios Technologies Corporation (Cambrios), as a California manufacturer of silver nanowires, is pleased to respond to the formal information request dated December 21, 2010 received from the Department of Toxic Substances Control (DTSC). In this response, Cambrios provides the following:

- The completed response form, including (a) a Material Safety Data Sheet responding to Section E of the form; (b) a spreadsheet responding to Section F of the form; and (c) a description of Cambrios' Test Method – 014 (Silver Content by Titration), which also responds to Section F of the form; and
- a "RoHS White Paper" dated July 15, 2010

The response form was completed to the best of our abilities and current knowledge of Cambrios's silver nanowires and their chemical and physical properties.

As you know, Cambrios has provided DTSC with a substantial amount of information already, on an informal basis, during DTSC's two site visits in 2010 and in other communications. Consistent with Cambrios' collaborative approach in its communications with DTSC, and in the continuing spirit of cooperation, we provide additional information not formally requested, the enclosed "RoHS White Paper," which was presented to the European Parliament. We include this document because it is a comprehensive summary of Cambrios Nano Silver material use, health and environment risk, and outlines the basis for a minimal life cycle hazard.

If you have additional questions or requests for information, please do not hesitate to contact me.

Sincerely,

Norbert R. Fronczak
VP of Operations, Cambrios Technologies Corporation
930 E. Arques Avenue
Sunnyvale, CA 94085
Direct: 408-738-7403
Fax: 408-245-2220
Cell: 408-916-8624

cc: Dr. Jeff Wong (at DTSC, with enclosures)
Dr. Neena Sahasrabudhe (at DTSC, with enclosures)
Attachments:

Cambrios Technologies Corp. 930 East Arques Avenue Sunnyvale, CA 94085

SF:27501091.1

STATE OF CALIFORNIA
Department of Toxic Substances Control

Health and Safety Code Section 57019 Chemical Information Call-in Information
for Nanometals, Nanometal Oxides, and Quantum Dots
December 2010

This enclosure is provided for your convenience. You may provide the requested information in writing, and attaching any supplementary materials or explanatory information, in letter or report form.

SECTION A: CHEMICAL(S) (check each one which applies for your company)

- | | | |
|---|--|--|
| <input checked="" type="checkbox"/> Nano Silver | <input type="checkbox"/> Nano Titanium Dioxide | <input type="checkbox"/> Nano Cerium Oxide |
| <input type="checkbox"/> Nano Zero Valent Iron | <input type="checkbox"/> Nano Zinc Oxide | <input type="checkbox"/> Quantum Dot(s) |

SECTION B: BUSINESS IDENTIFICATION INFORMATION (check one and complete items 1 - 10)

- | | | | | |
|--|--|--|--|--|
| <input type="checkbox"/> Sole Owner | <input checked="" type="checkbox"/> Corporation | <input type="checkbox"/> Limited Liability Company (LLC) | <input type="checkbox"/> Limited Liability Partnership (LLP) | <input type="checkbox"/> Unincorporated Business Trust |
| <input type="checkbox"/> Spouses' Co-ownership | <input type="checkbox"/> Registered Domestic Partnership | <input type="checkbox"/> General Partnership | <input type="checkbox"/> Limited Partnership | <input type="checkbox"/> Other: (describe) |

1. Name of Sole Owner, Corporation, Partnership, Institution, Other.

CAMBRIOS TECHNOLOGIES CORPORATION

2. Business Trade Name ("Doing Business As," if any)

3. Business Address (physical location of your business: street number and name, city, state, country, zip or postal code)

930 EAST ARQUES AVENUE, SUNNYVALE, CA 94085

4. Mailing Address (street name and number, P.O. box, city, state, country, zip or postal code, if different from 3)

5. Business Website Address(es):

CAMBRIOS.COM

6. Name of Owner, Responsible Corporate Officer, Partner, Other.

JOHN LE MONCHECK

7. Contact Information for Person in 6 above.

Name: *NORBERT FRONCZAK*

Title: *VICE PRESIDENT OF OPERATIONS*

Business Telephone: *408-738-7400*

Email: *nfroncza@CAMBRIOS.COM*

8. Number of Employees (California employees).

42

9. NAICS Code(s) for this business:

Primary:

325998

Other:

541712

Other:

10. Nano Chemical Business Type: (check applicable)

☒ Manufacturer

☐ Importer

☒ Researcher

SECTION C: CERTIFICATION (FOR THIS COMPLETE SUBMITTAL)

I am duly authorized to prepare and submit this information, as a formal response to the request pursuant to Health and Safety Code section 57019(d)(1), and certify the information and statements made herein, and in the attachments, are correct to the best of my knowledge and belief.

Name: (type or print)

NORBERT R. FRONCZAK

Signature:

N. R. Fronczak

Date:

12/15/2011

SECTION D: NANOMATERIAL CHEMICAL AND PHYSICAL PROPERTIES (Attach additional pages as needed)			
PRODUCT / PRODUCTION INFORMATION			
NANO CHEMICAL NAME: (Use a separate page for each unique chemical.)		Silver Nano Wires	
COMMERCIAL NAME(S): ClearOhm™ Ink			
ANNUAL PRODUCTION VOLUME: < 100 kg's of Silver Nano Wires			
PRODUCTION METHOD(S): Chemical Synthesis in a Liquid Phase			
IDENTIFICATION OF THE SUPPLIER(S): N/A - All Nano Materials are Produced Internally - No Purchased Nano Materials			
PARAMETER		VALUE / RANGE¹/ (include units)	NAME OF ANALYTICAL METHODS²/
PHYSICAL PROPERTIES			
SHAPE (MORPHOLOGY)		Nano Wires L= 10 - 200 um W=1 - 100 nm	Scanning Electron Microscopy (SEM) Photos and Light Microscopy
DENSITY		Unknown	
SURFACE AREA		1 - 30 m²/g	Calculated Value
PARTICLE SIZE DISTRIBUTION	Air	N/A	
	Liquid	See Shape (Morphology)	
	Solid / Powder	N/A	
Other (Specify)		N/A	
CHEMICAL PROPERTIES			
CHEMICAL COMPOSITION		Elemental Silver	X-Ray Diffraction/X-Ray Fluorescence
SURFACE MODIFICATION (COATING, FUNCTIONALIZATION)		Unknown	
PURITY		> 99%	X-Ray Diffraction
SURFACE CHARGE		Unknown	
DISPERSION³	Air	N/A	
	Liquid	Fully Dispersed	Scanning Electron Microscopy (SEM) Photos and Light Microscopy
	Solid	N/A	
IDENTIFYING AND DETERMINING CONCENTRATION OF NANO CHEMICAL, ITS METABOLITES, AND DEGRADATION PRODUCTS IN SPECIFIED MATRICES		Unknown	<u>Air:</u> NIOSH Method 7400 for Sampling and Transmission Electron Microscopy (TEM) <u>Surfaces:</u> Inductively Coupled Plasma Spectrometry (ICP) <u>Solution:</u> Titration internal method per procedure TM-014
Water, Air, Soil, Sediment, Sludge, Chemical Waste, Fish, Blood, Adipose Tissue, Urine, Other (specify)			
SOLUBILITY	Water Solubility	Unknown	
	Solubility in Organic Solvent	Unknown	
n-OCTANOL-WATER PARTITION COEFFICIENT		Unknown	
		Unknown	
STABILITY AND REACTIVITY	Flammability	N/A	
	Explosiveness	N/A	
	Oxidizing Properties	Unknown	
	Oxidation Reduction Potential	~ 0.4 V	Photoelectron Spectrometry
	Storage Stability and Reactivity (Container Material)	Shelf-life > 1 yr - For a solution of Cambrios silver nanowires/water/surfactant/visc osity modifier in a high density polyethylene container	Scanning Electron Microscopy (SEM) Photos and Light Microscopy
	Stability to Thermal, Sunlight, and Metal(s)	Thermal - Stable at > 300°C Sunlight - Unknown	Scanning Electron Microscopy (SEM) Photos and Light Microscopy



Material Safety Data Sheet

ClearOhm™ Ink-A Series

Section 1: Chemical Product and Company Identification

Product Name:	ClearOhm™ Ink-A Series**	Contact Information:
Synonym:	Conductive Ink	Cambrios Technologies Corporation 930 East Arques Avenue Sunnyvale, CA, USA Emergency Assistance: Chemtrec Phone, US: 800-424-9300 International: 703-527-3887 For non-emergency assistance: Phone: 408-738-7400 Fax: 408-245-2220

**Contains nanoscale material

Section 2: Composition and Information on Ingredients

Component:	Percentage:	CAS#:	EC NUMBER (EINECS):
Additives	0-10	Proprietary	Not available
Silver	0.1 – 5.0	7440-22-4	231-131-3
Water	85.0 – 99.9	7732-18-5	231-791-2

Section 3: Hazards Identification

Potential Health Effects:

Skin contact:	Acute Exposure:	May cause skin irritation.
	Chronic Exposure:	No information available.
Eye contact:	Acute Exposure:	Eye irritation.
	Chronic Exposure:	Eye Irritation.
Ingestion:	Acute Exposure:	No information available.
	Chronic Exposure:	No information available.
Inhalation:	Acute Exposure:	No information available.
	Chronic Exposure:	No information available.

Carcinogen Status:

OSHA: No

NTP: No

IARC: No

NFPA Ratings (Scale 0-4): HEALTH=1 FIRE=1 REACTIVITY=0

Section 4: First Aid Measures

Eye Contact: Check for and remove any contact lenses. In case of contact, immediately flush eyes with plenty of water for at least 15 minutes. Cold water may be used. Get medical attention immediately.

Skin Contact: Flush with copious amounts of soap and water for at least 15 minutes. Remove contaminated clothing and shoes. Cold water may be used. Wash clothing before reuse. Thoroughly clean shoes before reuse. Get medical attention immediately.

Inhalation: If inhaled, remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult,



give oxygen. Get medical attention immediately.

Ingestion: If conscious, wash out mouth with water. Seek medical attention immediately.

Section 5: Fire Fighting Measures

Flammability of the Product: Non Flammable

Flash Points: NA

Lower Flammable Limit: NA

Upper Flammable Limit: NA

Flammability Class (OSHA): NA

Fire Fighting Media and Instructions: Use regular dry chemical, carbon dioxide, water, regular foam

Section 6: Accidental Release Measures

Personal Precautions: When handling spills use appropriate personal protective equipment outlined in Section 8.

Indoor Spill: Promptly absorb spill onto an appropriate material. Collect and dispose of all waste in an appropriate chemical waste container in accordance with applicable laws.

Land Spill: Collect spilled material and transfer to D.O.T. container for disposal.

Water Spill: Do not allow release to water.

Section 7: Handling and Storage

Handling (Personnel): Wear appropriate personal protective equipment outlined in Section 8. Use of the material in a well ventilated and exhausted area should be considered. Avoid contact with skin and eyes.

Storage: Keep container tightly closed in cool storage. Recommended storage temperature: 5-10°C (41 to 50°F).

Section 8: Exposure Controls/Personal Protection

Engineering Controls:

Due to the nanoscale nature of this material the use of local exhaust ventilation should be considered to control emissions near the source. Laboratory samples should be handled in a fume hood. Use of mechanical ventilation of confined spaces should be considered.

Personal Protection:

Skin Protection: Use impermeable gloves and clothing during activities where there is potential for direct skin contact with the product.

Eye Protection: Use eye protection, such as splash resistant safety glasses/goggles. A secondary protection faceshield, should be considered. Provide an emergency eye wash station and quick drench shower in the immediate work area.

Inhalation Protection: Due to the nanoscale nature of the material use of respirators, in compliance with applicable laws, regulations, and standards, should be considered for tasks where local exhaust or fume hoods are not available.

Exposure Guidelines:

OSHA Hazards (29 CFR 1910.1200) Exposure limits 8 hrs. TWA (ppm)

<u>Component:</u>	<u>OSHA PEL:</u>	<u>ACGIH TLV:</u>
Additive	Not established	Not established
Silver	0.01 mg/m ³	0.1 mg/m ³
Water	Not established	Not established
Silver (Nanoscale)	Not established	Not established



Section 9: Physical and Chemical Properties

Physical state and appearance: Liquid

Odor: Odorless.

Molecular Weight: NA

Color: Gray

pH: NA

Boiling Point: NA

Melting Point: NA

Specific Gravity: NA

Vapor Pressure: Not applicable.

Solubility: acetone, benzene, carbon tetrachloride, ether, methanol, organic solvents

Section 10: Stability and Reactivity Data

Stability: Stable under ordinary conditions of use and storage.

Instability Temperature: Not available.

Hazardous Polymerization: Will not occur.

Conditions of Instability: Excess heat, incompatible materials.

Incompatibility with various substances: Strong oxidizing agents.

Corrosivity: None.

Special Remarks on Reactivity: Not available.

Special Remarks on Corrosivity: Not available.

Section 11: Toxicological Information

Routes of Entry: Inhalation. Ingestion.

Toxicity to Animals:

Additive

Acute Toxicity:

Oral	LD50	Rat	20 gm/kg
Oral	LD50	Rabbit	18500 mg/kg

Silver

Acute Toxicity:

Oral	LD50	Guinea pig	5 gm/kg
Oral	LD50	Rat	20 gm/kg

Silver (nanoscale) – not established

Chronic Effects on Humans: Not available.

Other Toxic Effects on Humans: Not available.

Special Remarks on Chronic Effects on Humans: Not available.

Special Remarks on other Toxic Effects on Humans: Not available.



Section 12: Ecological Information

Additive

Ecotoxicity Data:

Fish Toxicity: 610 ug/L 96 hour(s) LC50 (Mortality) Bluegill (*Lepomis macrochirus*)

Invertebrate Toxicity: >10,000,000 ug/L 48 hour(s) EC50 (Immobilization) Water flea (*Daphnia magna*)

Environmental Summary: Highly toxic to aquatic life.

Silver

Ecotoxicity Data:

Fish Toxicity: 58000 ug/L 96 hour(s) LC50 (Mortality) Sheepshead minnow (*Cyprinodon variegatus*)

Invertebrate Toxicity: 0.24 ug/L 48 hour(s) EC50 (Mortality) Water flea (*Daphnia magna*)

Algal Toxicity: 170 ug/L 96 hour(s) EC50 (Photosynthesis) Diatom (*skeletonema costatum*)

Fate and Transport:

Bioconcentration: 10250 ug/L 14 hour(s) BCF (Residue) Pacific oyster (*Crassostrea gigas*) 20 ug/L

Silver (nanoscale) – not established

Section 13: Disposal Considerations

Waste Disposal: The user of this product must properly characterize the waste generated from the use of this product in accordance with all applicable federal, state and/or local laws and regulations in order to determine the proper disposal of the waste in accordance with all applicable federal, state and/or local laws and regulations.

Section 14: Transport Information

Package and transport in accordance with Department of Transportation (DOT) and other regulatory agency requirements.

DOT Classification: Not regulated as a hazardous material

IATA: Not regulated as a hazardous material

Identification Number: Not applicable

Special Provisions for Transport: Not applicable.

Section 15: Other Regulatory Information

Federal and State Regulations:

OSHA Hazard Communication Standard, 29 CFR 1910.1200: Ensure that the hazards associated with this product are transmitted to employees by means of a hazard communications program, in accordance with federal and state Occupational Safety and Health Administration (OSHA) regulations.

CERCLA/SUPERFUND Hazard Category: At the time of this document's preparation, one or more of the ingredients of this product were listed in 40 CFR 302.4. The list should be periodically checked for applicable updates. Additive: 5000 LBS RQ and Silver, metal (as Ag): 1000 LBS RQ

SARA 313 Information: At the time of this document's preparation, none of the ingredients of this product were listed in 40 CFR 372. The list should be periodically checked for applicable updates.

Toxic Substances Control Act (TSCA): All of the compounds in this product are on the TSCA Inventory and/or are subject to a Low Volume Exemption.

California Proposition 65: At the time of this document's preparation, none of the ingredients of this product were included on the California Proposition 65 list of chemicals known to cause cancer or reproductive toxicity. The list should periodically be checked for applicable updates.

**Canadian Regulations:**

WHMIS Classification: Not determined.

European Regulations:

Cambrios Technologies Corporation (Cambrios) manufactured under the Lead Free Program is in compliance with European Union Directive 2002/95/95/EC (RoHS Directive) of the European Parliament and of the Council of 27 January 2003. Cambrios products are in compliance with RoHS and do not exceed the maximum limit for the following 6 designated substances.

<u>Substance</u>	<u>Maximum Limit (ppm)</u>
Cadmium (Cd)	100
Lead (Pb)	1000
Mercury (Hg)	1000
Hexavalent Chromium	1000
Poly Brominated Biphenyls	1000
Poly Brominated Diphenyl Ethers (PBDE)	1000

EC Risk and Safety Phrases: Not determined

German Regulations: Not determined

Section 16: Other Information

Issued: 5/13/11

Cambrios Technologies Corporation (Cambrios) safety practices follow current recommendations from the US National Institute for Occupational Safety and Health (NIOSH). All users must utilize worker protection measures and environmental release controls required by applicable laws, regulations, and standards, including applicable USEPA and OSHA regulations. Acknowledgement of receipt of this Material Safety Data Sheet shall be considered acknowledgement that the user will comply with these requirements.

The above information has been compiled from sources we believe to be reliable and, to our knowledge, is accurate. However, we make no warranty of merchantability or any other warranty, express or implied, with respect to such information, and we assume no liability resulting from its use. Users should make their own investigations to determine the suitability of the information for their particular purposes. In no event shall Cambrios be liable for any claims, losses, or damages or any special, indirect, incidental, consequential or exemplary damages, howsoever arising, resulting from any use of the above information even if Cambrios has been advised of the possibility of such damages.

SECTION F:		
	For each nanomaterial you produce or import, describe the analytical test method(s) that you use, or plan to use, to sample, prepare, and analyze a specific matrix to determine the identify and concentration of each specified nanomaterial. Use a sparate page to describe the procedure for each, individual matrix, which must include water, air, soil, sediment, sludge, chemical waste, fish, blood, adipose tissue, and urine. Include the information requested in Section D above.	
Analytical Test Methods Used at Cambrios:		
	Silver Identification in solids	X-Ray Fluorescence - method used is Thermo Electron VXR XRF Analysis System
	Elemental Silver Identification in solids	X-Ray Diffraction - Data is collected by a coupled Theta:2-Theta scan on a Rigaku Ultima-III diffractometer equipped with a copper x-ray tube, variable slits, parafocusing optics and a diffracted beam monochromator.
	Silver concentration in (dissolvable) components	Inductively Coupled Plasma Spectrometry (ICP) - NIOSH Method 7300
	Silver Wire Count in Air	Transmission Electron Microscopy (TEM) - NIOSH Method 7400
	Silver and Silver Ion Content in Liquids	Titration - Cambrios Test Method TM-014



TM-014	Silver Content by Titration	Frank Wallace/ Michelle Chan	4/2/09
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Reference Document(s)	
NA	

1. PURPOSE

Measure silver content in nanowire preparations by equivalence point titration of Ag^+ to AgCl .

2. ABBREVIATIONS/DEFINITIONS: NA

3. SAFETY

Wear gloves and safety glasses when handling nanowire solutions. Handle nitric acid with the utmost care.

4. MATERIALS/EQUIPMENT

Description	Part Number
Nanowire solution—purified in water, formulated in ink, or crude reaction mixture in propylene glycol	N/A
Mettler-Toledo T50 autotitrator equipped with DM141-SC combination silver ring electrode for argentometric Titrations	T50M
0.025M NaCl titrant	N/A
100 mL titration beakers	N/A
Nitric acid, 15.7M, equipped with manual volumetric addition pump	N/A
ZeroStat™ anti-static gun	N/A

5. INSTRUMENT VALIDATION & CALIBRATION: NA

6. PROCEDURE

STEP	PROCEDURE
1	Remove titrant tube from holder and place in titration stand.
2	Check tubing for bubbles. If bubbles are apparent, rinse with titrant (press "Rinse" icon on touch screen the "OK"). Touch "Home" button (shaped like a house) on the side of the touch screen when finished.
3	Remove the electrode from the KNO_3 storage solution. Rinse with DI water, dry with a Kimwipe, and place in the titration stand.
4	Remove rubber cap near the top of the electrode.



STEP	PROCEDURE										
5	Place a clean, empty titration beaker on the balance; discharge any static on cup using ZeroStat™ gun and tare balance (static on the cup will cause the balance reading to fluctuate even after it has been tared).										
6	Press the "Silver" icon on the touch screen.										
7	<p>Add sample to beaker according to the following table:</p> <table border="1"> <thead> <tr> <th>Approximate NW concentration (wt %)</th><th>Addition amount (g)</th></tr> </thead> <tbody> <tr> <td>0.05%</td><td>14</td></tr> <tr> <td>0.1%</td><td>7</td></tr> <tr> <td>0.5%</td><td>2</td></tr> <tr> <td>>2.0%</td><td>0.2</td></tr> </tbody> </table> <p>For testing of Ag⁺ in crude reaction mixture, add 2-10 g of sample.</p>	Approximate NW concentration (wt %)	Addition amount (g)	0.05%	14	0.1%	7	0.5%	2	>2.0%	0.2
Approximate NW concentration (wt %)	Addition amount (g)										
0.05%	14										
0.1%	7										
0.5%	2										
>2.0%	0.2										
8	Touch the "sample size" field. Touch "OK" when correct sample weight appears.										
9	Remove sample from balance.										
10	<p>For Ag content purified/water-based formulations, add nitric acid in 0.5 mL aliquots. Swirl between aliquots and repeat until all silver is dissolved and solution is clear. After the solution is clear, add one more aliquot to ensure that there is no more silver to be dissolved.</p> <p>Note: A small white polymer mass may be observed in formulations containing high molecular weight HPMC.</p> <p>For Ag content in PG crude or solvent-based formulations, dilute sample with at least equal parts water and add nitric acid in 0.5 mL aliquots. Swirl between aliquots and repeat until all silver is dissolved and solution is clear. After the solution is clear, add one more aliquot to ensure that there is no more silver to be dissolved .</p> <p>Note: Dilution with water prior to nitric acid addition is critical to avoid gas evolution and generation of potentially hazardous byproducts.</p> <p>For residual Ag⁺ in PG or water-based formulations, do not add acid—proceed directly to the next step.</p>										
11	Dilute sample with DI water up to ~40 mL in titration beaker.										
12	Place titration cup in stand and tighten compression ring.										
13	Press "Start" on the touch screen. Press "OK" when prompted to add sample.										
14	Once titration is complete, record weight % silver (displayed as R1 value). For PG titrations, the quantity measured is weight % unreacted Ag ⁺ .										
15	Remove cup. Discard contents in Acid Waste for Ag content tests, and in NW/PG waste for residual Ag ⁺ tests.										
16	Cleaning after Ag content tests: Rinse electrode, mixer and titrant tube with DI water and dry with Kimwipes.										
17	Cleaning after residual Ag⁺ content tests: Rinse electrode, mixer and titrant tube with DI water, then wipe electrode, mixer and titrant tube with ethanol-soaked Kimwipe. Finally, rinse electrode, mixer and titrant tube with DI water and dry with Kimwipes.										
18	Replace electrode in storage solution and close rubber cap near the top.										



STEP	PROCEDURE
19	Place titrant tube in holder on top of the titrant bottle.

7. ATTACHMENTS: NA

8. VERSION HISTORY

Rev	By	Date	Summary Description of Changes
01	F. Wallace/ M. Chan	3/24/09	• Clarified some steps in the process
01	B. Lerner	7/8/09	Corrected footer: title/doc# & confidentiality statement
02	J. Colonia	3/21/11	Updated Step 10



NANOSILVER BRIEFING PAPER

15 July 2010

I. EXECUTIVE SUMMARY

A proposed amendment to the recast of the Restriction on Hazardous Substances Directive (RoHS)¹ would effectively ban the use of nanosilver in electric and electronic equipment (EEE). Such a ban is not warranted for the use of nanosilver, including silver nanowires, as a constituent of transparent conductive films that can be used as components of touch screens, displays, and even solar energy photovoltaics. This novel use of nanosilver is vastly different than the biocidal use of nanosilver which appears to be the primary basis for the proposed prohibition. In contrast to the perceived risks of the use of nanosilver in biocides, the use of this nanomaterial in transparent conductive film poses negligible risk to human health, as demonstrated by workplace exposure studies undertaken by Cambrios Technologies Corporation ("Cambrios"), a U.S. manufacturer of silver nanowires. Further, the encapsulated form of the nanosilver in this application presents negligible risk of releases to the environment.

It is completely erroneous to assume that all applications of nanosilver in EEE pose the same risks as the biocidal use of nanosilver. Moreover, such an assumption ignores numerous benefits of the use described herein, including the fact that less overall waste occurs in this application than in currently used technologies involving metal oxides, that the use of nanosilver in this application increases the durability and lifetime of the EEE, and that the use of this technology promises the creation of new economic opportunities in the European Union ("EU"). Further, a blanket ban in the use of nanosilver in EEE in the EU, without proper consideration of all individual applications, will have the undesirable effect of stifling technological innovation in the EU not only with respect to EEE, but with respect to the development of other technologies including alternative energy technologies such as solar energy, in that, for example, these transparent conductive films may lead to more efficient and cost effective solar energy photovoltaics.

For all these reasons, and without conceding that the proposed amendment is appropriate in the first instance, this briefing paper proposes an exclusion from the proposed prohibition for nanosilver (including silver nanowires), as follows:

¹ Directive 2002/95/EC, available at:
<http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CONSLEG:2002L0095:20090611:EN:PDF>.

“Paragraph [x] shall not apply to nanosilver (including silver nanowires) used as a conductive constituent material in EEE.”

II. CURRENT DEVELOPMENTS WITH ROHS AND PROPOSED EXCLUSION PROPOSED BY INDUSTRY

As explained in further detail below, a proposed amendment to the recast RoHS Directive would prohibit nanosilver in EEE at levels above the detection limit for that substance. Yet nanosilver, in the form of silver nanowires, has unique applications in EEE. Furthermore, nanosilver in EEE is most often encapsulated in protective materials to isolate it from other materials and from the environment. In this form, it presents a minimal risk to the environment and end-users. Finally, transparent conductive layers of EEE components, such as displays, touch screens and other optical devices, made with silver nanowires possess 20 – 100 times less metal than comparable layers made with traditional transparent conductive materials, the most common of which is sputtered indium tin oxide (“ITO”), thereby contributing less overall waste. Accordingly, we request that should any provisions relating to nanomaterials be included in the recast RoHS, these should explicitly exclude nanosilver, including silver nanowires, used as a conductive constituent material in EEE.

A. Background

The current RoHS Directive entered into force on 13 February 2003. This Directive restricts the use of six hazardous materials in the manufacture of various types of EEE.² On 3 December 2008, the European Commission (the “Commission”) published a proposal to revise the Directive.³ On 28 February 2010, the European Parliament’s Committee on the Environment, Public Health and Food Safety (the “Environment Committee”) published a draft report amending the Commission’s proposed recast of the RoHS Directive.⁴

On 2 June, the Environment Committee voted on a final draft report, which added provisions regulating nanosilver and other nanomaterials⁵. One of the proposed

² The six hazardous materials that are restricted are: Lead (Pb), Mercury (Hg), Cadmium (Cd), Hexavalent chromium (Cr6+), Polybrominated biphenyls (PBB) and Polybrominated diphenyl ether (PBDE).

³ See <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2008:0809:FIN:EN:PDF>.

⁴ See <http://www.europarl.europa.eu/sides/getDoc.do?pubRef=-//EP//NONSGML+COMPARL+PE-430.424+03+DOC+PDF+V0//EN&language=EN>.

⁵ See press release at: http://www.europarl.europa.eu/pdfs/news/expert/infopress/20100531IPR75278/20100531IPR75278_en.pdf.

amendments in the final report would classify nanosilver as a prohibited substance in EEE, with a maximum concentration value ("MCV") in homogeneous materials at the detection limit for that substance.

B. *Proposed Exclusion*

Cambrios has numerous concerns regarding the proposed amendment relating to nanosilver and nanomaterials generally. Cambrios supports the Joint Industry Position on the Regulation of Nanomaterials in the Recast of the RoHS Directive (Restriction on Hazardous Substances), dated 6 July 2010.⁶ Focusing on the proposed nanosilver prohibition specifically, however, this briefing paper explains the basis for a proposed exclusion, should the proposed amendment be adopted.

As explained in this briefing paper, nanosilver in the form of silver nanowires and as encapsulated constituents of transparent conductive films, have novel and unique applications in EEE and promise to enhance the continuing development of EEE as well as other critical products such as more efficient and cheaper solar energy photovoltaics. The proposed prohibition of nanosilver as currently drafted by the Environment Committee will impede innovation in these novel applications, with a potential spillover adverse effect in the development of solar energy and possibly other alternative energy technologies. Moreover, these novel applications present minimal risk to human health and the environment. Accordingly, we request that any provisions on nanomaterials explicitly exclude silver nanowires and encapsulated nanosilver, as follows:

"Paragraph [x] shall not apply to nanosilver (including silver nanowires) used as a conductive constituent material in EEE."

III. NOVEL, NON-BIOCIDAL USE OF NANOSILVER

Cambrios is a U.S. electronic materials company that develops proprietary, competitive products using nanotechnology. Cambrios implements its novel technology to simplify electronics manufacturing processes, improve end-product performance and identify ways to satisfy unmet industry needs. Founded in 2004, it employs 40 workers and has recently launched its first products.

Cambrios has developed a novel, state-of-the-art transparent, conductive film, which uses nanosilver, in the form of silver nanowires, as a constituent. These films will serve as higher performing alternatives used in touch screens and electronic displays of EEE, in inorganic and organic thin film photovoltaics and in organic light emitting diode (OLED) lighting, thereby replacing current technology in these applications, sputtered ITO.

⁶

Available at: http://www.orgalime.org/Pdf/Joint_PP_Nanomaterials_in_RoHS_Jul10.pdf.

Significantly, the use of nanosilver-based conductive films would simplify the process for manufacturing EEE components, as compared to the use of sputtered ITO. This simplified process has a very positive economic implication for EU companies, either by allowing them to enter the EEE transparent conductive component manufacturing business, a market measuring in the hundreds of millions of Euros, or by allowing a contraction of the supply chain. In the latter case, manufacturers in the EU of photovoltaic or lighting devices could perform their own coating operations rather than buying components from Asia. Currently, the sputtered ITO technology presents manufacturing obstacles to such EU companies, and Asian companies have entered the void to now dominate the worldwide market. The simpler manufacturing process afforded by nanosilver-based conductive films removes these manufacturing obstacles, thereby giving EU companies a new opportunity to participate in the market. Cambrios and several EU companies, located in Italy, Belgium, The Netherlands, Germany and England, are engaged in technical collaborations and product development discussions. Some of these discussions already are in the contract negotiation stage. In the absence of the proposed exclusion requested in this briefing paper, the nanosilver ban will guarantee that the door to this new EU economic opportunity will remain locked.

Aside from greater ease of use, silver nanowire-based transparent conductive films are superior to ITO or other metal oxide-based films and provide greater benefits. Among other things:

- 20-100 times less metal is required, thereby decreasing overall waste;
- Nanowire-based films are more durable than ITO-based films, increasing durability and improving the lifetime of many EEE components, including touch screens;
- Nanowire-based films are deposited in aqueous solvents using precision wet-coating processes and equipment that minimize waste in comparison to metal oxide films that are deposited as a gas, a process by which up to 80% does not become incorporated into the target substrate;
- More transparent and flexible than ITO- and metal oxide-based films, silver nanowire-based films can be used to manufacture low-cost, more efficient, lightweight and flexible solar photovoltaics;
- Silver nanowire-based conductive films have optical and electrical properties superior to ITO based films;
- Unlike the more rigid ITO-based films, silver nanowire-based films, with their greater flexibility, are much better suited for novel device designs.

Currently, Cambrios manufactures the silver nanowire-based conductive material in the United States. Using a batch liquid chemical process conducted in completely enclosed systems housed in a tightly environmentally-controlled clean room environment, silver nanowires are synthesized via a chemical reaction based on a

published method⁷, generating nanowires in the dimensions of 15 – 100 nanometers in diameter and 2-50 microns long. The nanowires are then suspended in a coating solution consisting primarily of deionized (DI) water. Cambrios' customers include manufacturers of EEE and intermediate manufacturers downstream of Cambrios in the EEE supply chain, some of which could be located in the EU. Ultimately, EU retail customers will purchase or make use of EEE containing nanowires made by Cambrios for use in their homes or places of work.

The silver nanowire coating material is to be sold to industrial customers in one of two forms:

- *As a suspension, i.e., an “ink,” that the customer would use to coat electronic device components such as electronic liquid crystal displays or thin film photovoltaics.* The industrial customer would follow the deposition of the ink on the electronic device component with the application of an encapsulation layer such as a clear polymer that fixes the nanowires in place to serve their purpose as a transparent electrode, making up part of the device's circuitry. Alternatively, the next layer in the device structure may serve as the encapsulation layer. Note that most electronic devices cannot withstand environmental exposure, and thus encapsulation is very common to protect the electronic circuits from environmental degradation.⁸
- *As a component of coated substrates, such as glass or polyethylene terephthalate (PET) film, to be used in the manufacture of touch screens, touch computers, and the like.* In this form, the silver nanowire ink is deposited on the substrate, and then a UV curable polymer overcoat is applied. This coated substrate currently is manufactured by Cambrios in Japan.

In both forms, the silver nanowires become fully encapsulated within a matrix, typically consisting of a cured polymer overcoat.

The EEE components, bearing the silver nanowire transparent conductive film, ultimately would be incorporated into consumer products such as cell phones, computers and office machines. In these end use products, the silver nanowires remain embedded in the polymer overcoat. The EEE itself would generally add an additional layer of encapsulation; for example, glass and additional laminated layers in touch screens create further barriers between the device and the user. *Therefore, during use of such consumer products, no release of nanosilver in any form would be expected to occur.*

⁷ “Crystalline Silver Nanowires by Soft Solution Processing,” *Nanoletters* 2002 2(2), pp. 165-168.

⁸ As an extreme example, roof-top solar cells need to be encapsulated with sophisticated barrier materials to allow for long term (20+ years) reliability.

IV. MINIMAL RISK TO HUMAN HEALTH AND THE ENVIRONMENT

As described further below, the use of nanosilver in the applications described here, *i.e.*, encapsulated silver nanowires, presents minimal risk to human health and the environment. As an initial observation, the entire touch panel and flat panel market size, combined, would be served by an extremely small amount of silver nanowires: a total of 7,100 kilograms per year, *worldwide*. It would take many years, however to even achieve market penetration at a substantial level.

Beyond that, repeated studies undertaken by Cambrios, the U.S. manufacturer of silver nanowires, have demonstrated that no worker exposure occurs during manufacture and industrial use of silver nanowires.⁹ In addition, because the nanowires are embedded in a polymer overcoat in the ultimate end products, no exposures to consumers or product end-of-life dismantlers would be expected to occur.

As for environmental releases, no uncontrolled environmental releases of silver nanowires would occur. Waste streams generated by coating silver nanowire ink on to EEE components are managed as hazardous waste during industrial use. The encapsulation of the nanowires in the industrial use films, as well as in the electronic device end products onto which the films are adhered, would preclude migration of the nanowires into the environment.

A. *Negligible Human Exposure*

1. *Industrial Users*

Silver nanowire synthesis occurs in strictly controlled conditions using standard laboratory practices for health and safety. Personnel must wear personal protective equipment such as lab coats, impermeable gloves, goggles and masks. Accordingly, workers are unlikely to be exposed to nanosilver during the manufacture of silver nanowires.

As part of their normal operations, industrial users of the silver nanowire ink and the coated substrates in the EU would be expected to use those materials under controlled conditions so as to ensure that the device components they manufacture meet performance specifications. Use of the silver nanowire products occurs in conditions where ventilation is controlled. In fact, Cambrios' material safety data sheets ("MSDSs") for its silver nanowire products state:

The use of local exhaust ventilation is recommended to control emissions near the source. Laboratory samples should be handled in a fume hood.

⁹ "Exposure Assessment of Silver Nanoparticles, New Bedford, Massachusetts," Exponent (January 2007).

Provide mechanical ventilation of confined spaces. Use explosion proof ventilation equipment.

Such controlled conditions also effectively would protect workers as well. Moreover, industrial users of the inks and coated substrates (or any industrial chemicals, for that matter) routinely use engineering controls and personal protective equipment (“PPE”) as part of their usual operations. These protective measures reduce the risk of worker exposure to all the constituents of the silver nanowire products, including the silver nanowires themselves. In fact, Cambrios’ MSDSs require that impermeable gloves and clothing, as well as eye protection, be worn. Thus, worker exposure to silver nanowires would not be expected to result from the industrial use of these products.

This conclusion has been confirmed in workplace exposure studies of Cambrios’ silver nanowire inks and coated substrates. In 2007, Cambrios commissioned a study evaluating worker exposure to silver nanowires under actual conditions of coating a PET substrate with silver nanowire ink, followed by the application of a UV curable polymer overcoat, and then subsequent curing of the overcoat and cutting of the coated substrate. These are operations virtually identical to those that would be undertaken by industrial users of the inks and coated substrates.

Numerous work area and personal air samples were taken throughout the course of these operations and analyzed in accordance with standard NIOSH¹⁰ methods established to detect and measure asbestos fibers, NIOSH Methods 7400 (using phase contrast microscopy) and 7402¹¹ (using transmission electron microscopy, or “TEM”). The samples also were analyzed for total silver quantification (using NIOSH Method 7303). *The results showed no detection of silver nanowires.*

To confirm that the methodology used in the workplace exposure study was appropriate for the detection and measurement of silver nanowires, Cambrios undertook a study of aerosols, created under closed and controlled conditions, of silver nanowires in known amounts.¹² The nanowire aerosols were captured on a filter; the silver nanowires were then measured using TEM and total silver analysis. The results of this validation study demonstrated that the filters used in the workplace exposure evaluation were more than 99.9% efficient at capturing silver nanowires in an aerosol. The validation study therefore confirmed the results of the workplace exposure study, *i.e.*, that worker exposure to silver nanowires is negligible during the course of typical operations.

¹⁰ National Institute for Occupational Safety and Health.

¹¹ NIOSH Method 7402 was modified slightly due to the small diameter of the nanoparticles of interest. A Yamate Level II preparation method was used, which ensured that all captured fibers of 50 nanometers or greater were counted. In addition, a microscopy magnification level of 20,000X was used instead of 2,500X.

¹² These aerosols were artificially created in order to study the correlation of silver nanowire measurements on filters to the known amounts of silver nanowire in the aerosols. Under actual conditions of use, no silver nanowire aerosols would be expected to be generated – a prediction confirmed by the workplace exposure evaluation itself.

2. *Consumers Of EEE*

As incorporated into EEE components, the silver nanowires are encapsulated in a polymer overcoat matrix. Accordingly, the ultimate end use products, into which the components are incorporated, would not be expected to release silver nanowires during end product use. In fact, permanent attachment of the silver nanowires to the EEE component is necessary for the device to function at all. In addition, it is generally necessary to protect EEE components from solvents that might convert metallic silver to silver ions. In contrast, biocidal applications of nanomaterials often involve (and may even require in some instances) contact of the nanomaterial with water and surfactants. Thus, the operational context of nanosilver in EEE is vastly different than that of biocidal nanosilver, concerns about which appear to be the basis for the proposed RoHS amendment.

Moreover, nanosilver used as a biocide often presents the opportunity for direct skin contact with consumers and possible ingestion or inhalation. It is clear that provisions on nanomaterials, and their underlying bases, which are relevant to cosmetics and were recently introduced in Regulation 1223/2009 on cosmetic products, do not serve any purpose for EEE where, as here, no such direct skin contact is likely to occur. Similarly, the basis for concerns regarding human exposure resulting from nanosilver used in washing machines and refrigerators, where the nanomaterials are, in most and perhaps all instances, *intended* to be released, simply have no relevance to nanosilver to be used in an encapsulated, protected form in EEE components.

3. *Dismantlers Of EEE*

An important part of managing EEE waste is the recycling of devices and their components. Such activities necessarily entail some amount of dismantling of the devices by workers. Just as no consumer exposure to silver nanowires would be expected to occur because of the nanowires' encapsulation in the polymer coated matrix, no exposures to silver nanowires would be expected to occur during the course of dismantling EEE at the end of their lives. Even grinding activities would not be expected to result in exposures to the silver nanowires: the particles resulting from grinding activities would be expected to be much greater than nanoscale, and therefore the nanowires would be expected to remain embedded in the particle matrix.

B. *Negligible Release To The Environment At End Of Product Life*

At the end of their useful lives, EEE are intended to be dismantled and their components recycled. In contrast to cosmetics, where nano provisions were recently introduced in Regulation 1223/2009 on cosmetic products, for EEE, there exists a take-back and treatment policy in the Waste Electrical and Electronic Equipment ("WEEE") Directive 2002/96/EC. Nothing in the silver nanowire inks or coated substrates would present obstacles to that activity, or create risk of environmental release of the silver

nanowires. Because the silver nanowires remain embedded in the polymer overcoat matrix, no migration of the nanowires into the environment would be expected to occur.

C. *Minimal Hazard*

The above discussion demonstrates that there is negligible risk to human health and the environment resulting from the use of encapsulated nanosilver, in the form of encapsulated silver nanowires, as a constituent of conductive films on EEE touch screens and displays. Such negligible risk justifies that nanosilver, in such encapsulated form, should not be restricted or banned under the recast RoHS. From a regulatory point of view, these useful materials should not be treated the same way as nanomaterials designed for biocidal applications, which may be widely dispersed into the environment. Beyond the negligible human exposure and environmental releases associated with the use of nanosilver in conductive films, there also appears to be little hazard-based justification for the proposed general prohibition on nanosilver in EEE.

Nanosilver is used in an increasing number of products. Of the greater than 800 consumer products that contain nanoparticles, approximately 30% are thought to contain silver nanoparticles. Some of these uses may result in environmental release or human exposure but others, such as the use in EEE, may result in negligible human exposure and release to the environment. A recent comprehensive review¹³ of nanosilver prepared by the National Institute of Public Health and the Environment (“RIVM”) in the Netherlands summarized the available scientific information concerning the potential hazards of nanosilver. The RIVM scientists propose that researchers attempt to validate the authors’ hypothesis that the toxicity of nanosilver is proportional to the release of silver ions. The implication of this hypothesis is that nanosilver may present no new hazard for human health or the environment. Although some gaps in knowledge were identified in the RIVM analysis, the recommendation of the Institute is that release patterns and release kinetics from *specific* applications should be evaluated in depth. The authors’ recommendation that each application of nanosilver be assessed individually would only be supportable if some uses would be expected to result in negligible risks. Put another way, if all applications of nanosilver posed significant risk to human health or the environment, the authors’ recommendation would make no sense.

Although uncertainties at this time may argue against uncontrolled releases of nanoparticles to the environment, available data do not provide support for a level of environmental concern warranting prohibition of this promising and increasingly widely-used technology – especially in the application described herein, in which studies have demonstrated negligible human exposure and the encapsulated nature of the silver nanowires preclude migration into the environment.

¹³ Wijnhoven *et al.*, (2009). Nano-silver – a review of available data and knowledge gaps in human and environmental risk assessment. *Nano-toxicology*. 3(2):109-138.

V. CONCLUSION

The use of nanosilver, including silver nanowires, in transparent conductive film is a novel application posing negligible risk to human health and the environment. The proposed ban on the use of nanosilver in EEE, as set forth in the proposed amendment to the recast RoHS, is not based on considerations specific to this application, such as the negligible risks posed and the benefits that would accrue from this use. Rather, the proposed ban is based on concerns arising from a vastly different use of nanosilver, *i.e.*, as a biocide. The proposed ban could create an adverse impact not only on the advancement of EEE technologies and the EU economy, but also on other applications of silver nanowire transparent conductive film, including the development of more efficient and lower cost solar energy photovoltaics. Accordingly, if the proposed amendment is adopted, it should exclude nanosilver, including silver nanowires, used as a conductive constituent material in EEE.

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OF THE RETURN ADDRESS, FOLD AT DOTTED LINE

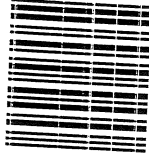
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